Behavioural Analysis of the Tower Controller Activity

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Abstract

In this paper we report on an initial study concerning the importance of direct observation for control tower activity. The results confirm that looking outside of the window is the most frequent and longest activity of the tower controller, occupying him for roughly 30-40% of the time. Two other significant activities were scanning radar image and strips. The change of attention between these three information sources is frequent but not in a defined order.

Introduction

This research is motivated by our interest in studying the applicability of augmented reality technology for ATM. Our assumption is that augmented reality has the biggest potential when the human operator, the air traffic controller in our case, is largely dependant on visual information, i.e. information retrieved by direct observation of the real world scene. Therefore we focus on tower operations.

We want to research the importance of direct observation for the tower control activity. In particular, we want to find out if direct observation provides unique information (i.e. not available from other sources) and, ultimately, which information can be obtained by it. Once we know this we may be able to design augmented reality environments which assist the tower control activity.

In this paper we report on an initial study concerning the direct observation, concretely, we conducted observation of the tower controller activity at one of the European airport. The study intended to investigate the major behavioural activities such as looking outside the window, manipulating with strip, scanning radar view or issuing clearances.

Related work

Previous studies concerning head-up time were mostly related to the pilot's performance in order to investigate head-up displays applicability. There were only few studies conducted for tower environment. The Grossberg study on Local Controller's activity showed that they spend 70% of their time looking out of the window and at radar image, and 21% time was addressed to strips. (Grossberg, 1995, Cardosi, Yost, 2001).
Bruce study (Bruce 1996, Caradosi, Yost, 2001) reported 38% time of looking out the window for Local Controller and 47% for Tower Controller.
Another study related to Local Controller and Ground Controller conducted by Pavet (Pavet, 2001) demonstrated 20 % of controller time oriented through the window.

The most complete study investigating the head-up and head-down issue, using video based eye/head tracking was conducted by Hilburn (Hilburn, 2004a). The study concerns Ground and Tower positions at major European airport with declared capacity of 80 movements per hour. There were two site of the airport (A and B) recorded with runways dedicated both for landing and departure. The results for the Tower position for site A are head-up time 44% and for site B 43%. Analogically for Ground position at site A, the head up time was 49% and 48% for site B. In contrary the head-up time during real time simulation for Tower position was very low (overall 12%), what might be explained by introduction of a A-SMGCS tool that required dead-down manipulation during this simulation or simply as a simulation effect or (Hilburn, 2004b).

In summary, excluding the Pavet's results, the majority of research showed that looking out of the window was the key activity of Tower

Controllers, occupying them roughly 40-50%.

Condition of observation

The observation was performed at Arlanda Airport (Sweden) on 27 April 2005. There was a Tower Controller working position recorded, between 14.00 and 15.00 hour. The position was facing runway 2 (RWY26) that was exclusively assigned for landing. The recording was taken during the day shift under the good visibility conditions. There was no traffic restriction. The total number of landing aircraft during the observation time was 22 whereas the declared arrival capacity at Arlanda Airport is calculated as 38 aircraft landings.

Methodology

The observation was based on the camera recordings and the audio of the controller; there were no recordings of the pilots' communication available. The camera was placed slightly aside of the controller, out of his line of sight.

The recording involves two controllers working at the tower control position. The first controller was filmed from the beginning of his shift up to the hand off (50 minutes), whereas the following controller was filmed only at the beginning of his shift (remained 10 minutes).

The amount of collected data for both controllers was not equal; therefore we did not carry out a comparison between the performances of both controllers.

The observation exclusively concerned the behavioural activity of the controller. The following activities were distinguished in order to the describe controller's performance:

- *Window* when the controller was looking outside the window in front of his position. As a subcategory there is the usage of binoculars marked, describing a period when the controller is supporting vision with binoculars.
- *Radar* describes the time when the controller was looking or manipulating with a radar or screen providing the meteorological information.

- *Strips* describe the time when the controller was scanning, ordering or writing on the strips.

- *Strips delivery* describe the time when the controller was out of the working volume, allowing him to scan the window in order to provide strips to other positions.

- *Coordination* describes the activity when the controller discussed and arranged traffic between the Ground control, Supervisors or Flight Data Assistant.

- *Clearance* describes issuing clearances. There were two kinds of instructions remarked: *Landing* describes issuing instructions for aircraft that are still airborne ("clear to land" and "continue approach"), *Runway vacated* describes issuing instruction to aircraft that already landed ("contact ground").

- *Non active* describes the time when a controller was not occupied with control activity. Due to low level of traffic, he was involved in other activities (chatting with others, resting) while remaining in his position.

We used the Interact software (www.mangold.de) to record parameters of activities, produce graphic representation of data and obtain basic statistic analysis.

Observation results

For the analysis the frequency of occurrences and duration of activities were measured. Frequency is calculated as a total number of occurrences and duration is the time of the activity. One occurrence of a particular activity is defined as continuous action without interruption. Any distraction was treated as the suspension of action and started a new occurrence. Both parameters are plotted in the Figure 1.

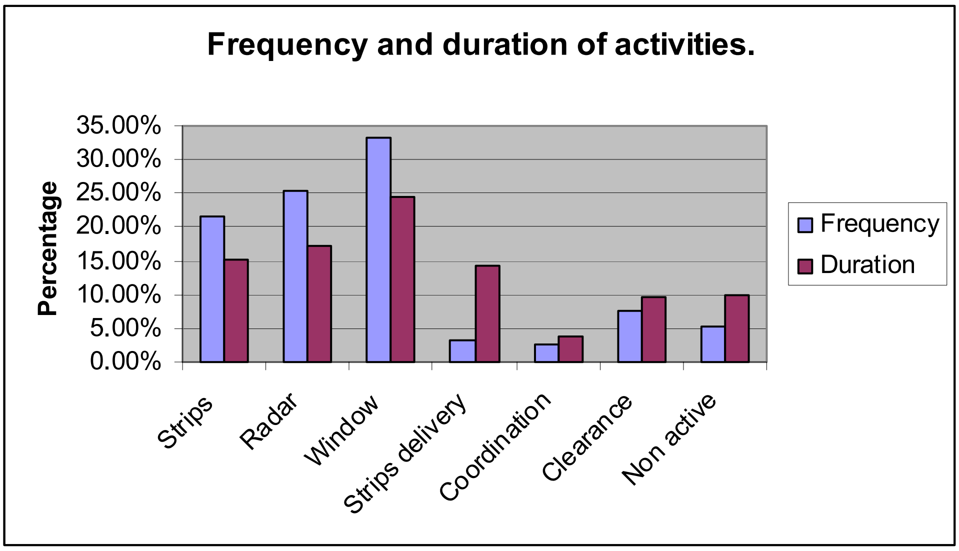

Figure 1 Frequency and duration of activities.

The major occupancy of the controller, both for frequency and duration, was looking outside of the window (frequency at the level of 33% and duration 25%). This category includes the binoculars usage (frequency 0.5%, duration 2%). Those results are consistent with research results (Hilburn, 2004a, Pavet, 2001, Bruce, 1996) and confirm that direct observation is prime activity for tower control.

Two other significant activities were “radar“ (frequency 25% duration 17%) and “strips” (frequency 21%, duration 15%). The high level of frequency within window/radar/strips activities showed that the controller is constantly switching attention between those three main sources of information. The information provided by radar including the screen with meteorological condition or manipulating with strips required head-down time, whereas the looking outside is head–up activity. The controller regularly refocuses his vision between direct observation at great distance and the radar image on his desk.

“Strips delivery” activity is particular comparing with others. Following the results, the frequency of occurrences was only 3.13%, but the duration was high, 14.06%. That might be explained by the fact that the observed tower position was assigned only for landings that are more predictable than departures. The controller anticipated incoming traffic; therefore he could leave the position for longer stretches of time.

The Figure 2 is a graphical representation of pattern of performed activities. Vertical lines in colours present the occurrence of the activity. The thickness of the line indicates the duration of the activity. A black line indicates the time of hand off. The symbols of aircraft represent the reconstructed time of landings. Following the figure we can again confirm that the controller was mostly occupied with scanning radar, window and strips.

The activity “clearance” was divided into two subcategories: *landing* and *runway vacated* in order to find out what kind of information are meaningful for the controller that manages airborne or already landed aircraft. There is noticeable difference between the numbers of instructions issued when aircraft is still airborne and clearances issued after landing. This phenomena could be explained by fact that controllers do not issue instructions “contact ground” for the pilots who are expected to be familiar with the airport.

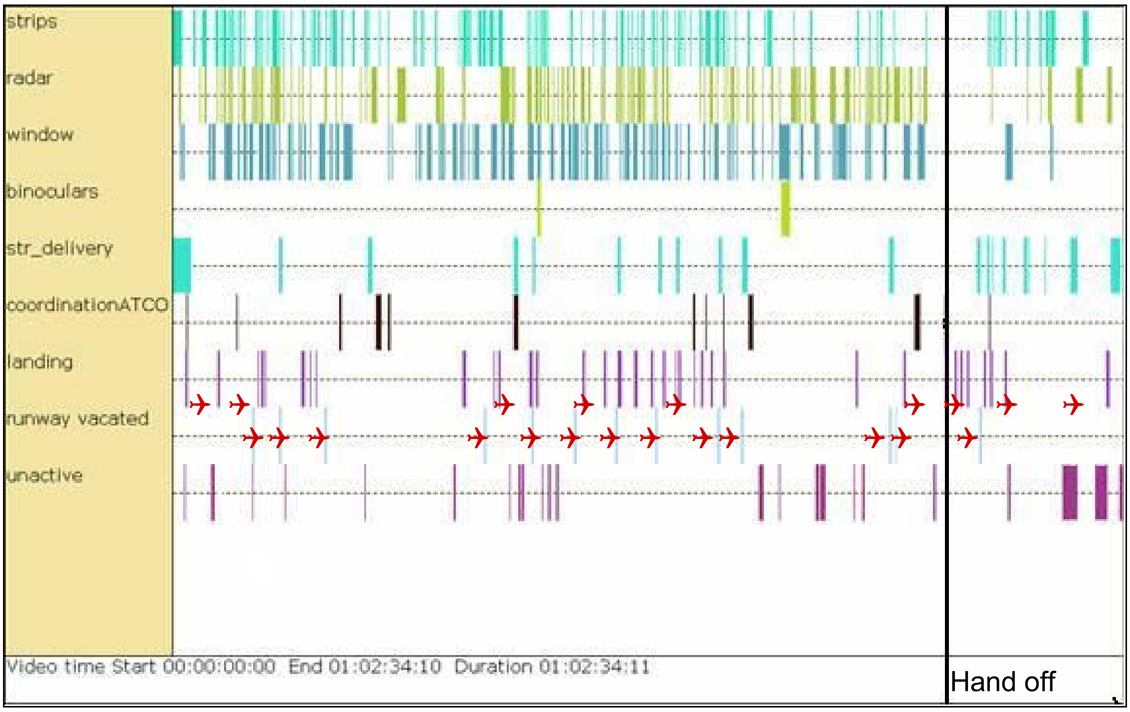

Figure 2 Pattern of activities.

We intended to analyse the scanning pattern of monitoring the traffic situation, therefore we analysed the sequence of activities.

Results interpreted as transition probabilities are presented in the Table 1. The activity placed in a column will be followed by an activity placed in a row with the given probability. The highest probabilities are highlighted in red. The transition probability indicates that the controller was constantly switching his attention between the radar, window and strips.

Additionally we did not define any special pattern for airborne and landed aircraft as it is seen from the two last rows of the table.

We can not define any fixed order between “radar”, “window” and “strips” activities but definitely those three are the prime activities performed by controller.

<u>Preliminary Conclusions</u>

This initial experiment confirms that looking outside of the window is the most frequent and longest activity of the tower controller, occupying him for roughly 30-40% of the time. Besides looking out of the window, the controller is dividing the major part of his attention over two other sources of information: the radar image and the strips. The change of attention between these three information sources is frequent but not in a defined order.

The infrequent, but long activity of strips delivery indicates that the tower controller can leave his position for longer stretches of time without impairing his performance. We conclude that the controller is therefore not restricted to stay within a limited volume of working space which gives him instant access to all information sources. This allows us to relax the design requirements on the experimental visualization environment.

<u>Future work</u>

Presented analysis was based on small sample of the controller’s activity and should be consider as a pilot study. To increase reliability of results, it is required to perform additional observations with a larger number of controllers and longer performance sample The controller’s performance might be dependent on meteorological conditions (high versus low visibility), night/day conditions or traffic level (peak versus low traffic) therefore future observations should be conducted under varying conditions. Performance might

		Radar	Strips	Window	Co-ordin.	Non active	Strips delivery	Clearance Landing	Clearance Runway	Sum	Pi
Radar		0.304	0.255	0.293	0.016	0.038	0.038	0.038	0.016	0.998	0.254
Strips		0.342	0.31	0.215	0.032	0.019	0.032	0.044	0.006	1	0.219
window		0.201	0.127	0.525	0.012	0.053	0.016	0.041	0.025	1	0.337
Co-ordin.		0.15	0.15	0.2	0.25	0.05	0.05	0.15	0	1	0.028
Non active		0.154	0.077	0.256	0.026	0.359	0.026	0.077	0.026	1.001	0.054
Strips delivery		0.217	0.304	0.043	0.13	0.043	0.043	0.13	0.087	0.997	0.032
Clearance	Landing	0.214	0.286	0.238	0	0	0.071	0.19	0	0.999	0.058
Clearance	Runway	0.231	0.385	0.231	0	0	0.077	0.077	0	1.001	0.018

Table 1Transition probabilities.

as well be task dependent e.g. departures versus landings. It would be interesting to reconstruct the gaze of the controller in parallel to the traffic in order to capture precise information of where the controller visual attention is located.

Also we need debriefing interviews with controllers in order to identify more detail what "looking out of the window" brings.

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